A Frequency Signature Based Method for the RF Identification of Letters

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***Abstract*— A method to identify, thanks to RF signals, the letters of the alphabet is presented in this paper. Every letter, when integrated, or realized with metallic strips, on dielectric substrate and excited with an electromagnetic wave exhibits an electromagnetic signature. This signature is unique and characterizes the RCS of the radiating letter. Consequently, it could be used for identification/recognition purposes.**

A frequency domain approach has been applied to a set of letters corresponding to the standard alphabet. Simulation results obtained with CST Suite® are presented and discussed in this paper. The experimental results corresponding to Arial font of 24mm are carried out and compared to theoretical predictions. Very good agreement between measurement and simulation is observed. Considering the signature of each letter it is possible to establish an algorithm for letter recognition and identification without errors.

***Index Terms*— RFID, Chipless, Letter Identification, RCS**

I. Introduction

RADIO Frequency Identification (RFID) is an automated wireless data capturing technique, which utilizes radio frequency (RF) waves for data transmission between the transponder and a reader [1]. RFID traditionally uses an IC chip inside the transponder to store the information regarding the item to be identified. RFID reader could be used to retrieve this information which is later relayed to a data base for processing. RFID tags have the potential to capture the large barcode market and many other potential markets have been identified. RFID offers lot of advantages over barcode such as larger read range, no constraint of Line of Sight, complete automation and larger amount of information storage capacity. Moreover, RFID tags can be custom built according to the application and can work in harsh environments [2]. However, in spite of all these advantages, cost of RFID tag still remains a huge factor, which has curtailed its influx into the market [3]. This made it imperative to develop an alternate low cost way of object and item identification. As a result, over the years, a lot of research effort has been devoted towards developing chipless RFID technology [4,5]. Besides reducing the cost of tags, chipless devices are fully integrable and can be directly realized onto the products. One attractive alternative is to consider the printed information on the item or its packaging as an identifier. This supposes that the marked information (letters, numbers, specific signs …) have specific and unique characteristics that allow their identification.

A previous work [6] of M. Keskilammi et al. has shown that some metallic words can be used to design antenna, so that it can serves at a time for advertising and as radiating element. In this paper we consider the signs of the alphabet and we present a method for the RF Identification of the letters. This method exploits the electromagnetic signatures of the alphabets in frequency domain. The aim is to demonstrate that different letters of the alphabet exhibit different electromagnetic signatures i.e. the characteristics of the signal in frequency domain would be different and this could be recorded in advance and used to identify the correct letter.

In Section II we present the principle of the proposed method. The electromagnetic signatures of the 26 letters are presented and discussed. Thus a strategy for classification and identification is carried out. In section III, experimental measurement setup and practical results of real letters have been discussed and compared with the simulation results. Lastly, conclusion and scope for future work is presented.

II. Concept Of The Approach

When a plane wave impinges any conducting body, free electrons start to move which leads to surface currents. The path of surface currents would depend on the polarization of the wave and shape of the object. Because of the surface currents the object starts radiating electromagnetic waves having specific characteristics. So, the object could be seen as a radiating source but the backscattered signal is quite dependent on the illumination signal and more specifically on

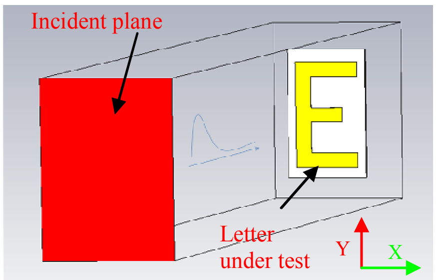

Fig. 1. Principle of the method of analysis.

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978-1-4244-9606-8/11/$26.00 ©2011 IEEE

the Radar Cross Section (RCS) of the conducting body.

Our purpose in this work is to analyze the electromagnetic signature of the conducting body, which can be a letter of the alphabet. For purpose of application, we restrict our study to the farfield response. Fig.1 shows an example the principle of the analysis method.

The backscattered signal of a metallic letter (realized on a thin and low permittivity substrate) is simulated thanks to CST Microwave Studio®. A plane wave excitation was used for the analysis and probes were set to record electric field and RCS in farfield region for the frequency band 1 to 10GHz.

Depending on the length of induced surface current path we could observe peaks in the frequency spectra of the body. Since alphabet differs from each other in shape, so for most of the letters electrical length is different which leads to different resonant frequencies. The position of these peaks in the frequency domain could serve as a way of identification of the letter of a given alphabet.

III. Application To Arial Fonts

Although there exists infinite possibilities of fonts for alphabets, we chose Arial fonts for our analysis owing to its simplicity and widespread use. A font height of 24 mm was chosen as standard. All the results for other font sizes could be expressed as a proportionality constant, for results of this size. The letter shapes were drawn in AUTOCAD 2010 with the help of "explode" text option. These shapes were later on imported to CST simulator for the analysis. Initially the alphabets were analyzed with plane wave propagating along the "z" direction and vertically polarized field along the "y" axis. Alphabet sample was placed in the "xoy" plane. Both X and Y components of the farfield were recorded but Y component (component along transmitting antenna's polarization) is of more interest to us since we were interested in using monostatic configuration for the measurement setup. Simulations were done for all the 26 letters of the alphabet and according to the obtained data letters of the alphabet have been categorized into groups to simplify their classification. Consequently we defined three complimentary groups:

A. *Letters showing peaks in 2-3 GHz*

TABLE I

First Resonant Frequencies for C, E, G, S and Z

Letters	C	E	G	S	Z
Resonant frequency (in GHz)	2.4	2.8	2	2.54	2.89

This group comprises of the letters "C", "E", "G", "S" and "Z". The common property binding them is their higher electrical length among all the letters when considered in vertical polarization. The surface currents take one continuous curved path along the whole length of alphabets as shown in Fig.2, and this leads to quite sharp resonant peaks in the frequency range 2-3 GHz.

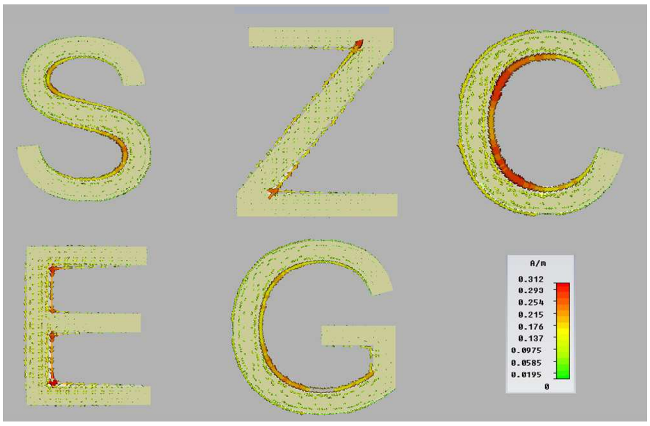

Fig. 2. Surface Current Plot for Alphabets C, E, G, S and Z.

One of the reasons of the sharp peaks is also the parasitic capacitive introduced because of the bending of the structure. This increase in capacitance improves the quality factor of the letter as a radiator.

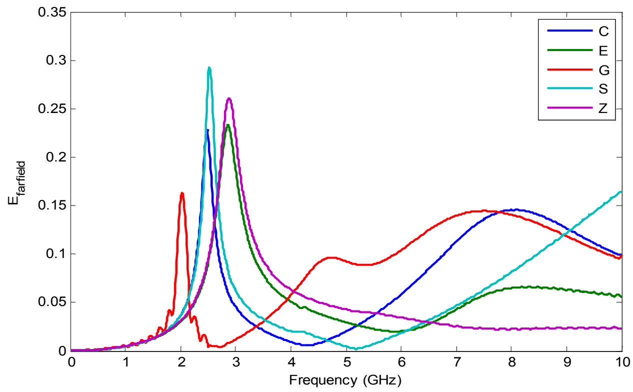

Fig. 3. Efarfield versus Frequency for Alphabets C, E, G, S and Z.

The resonant peaks of the alphabets are sufficiently apart for clear distinction and have been shown in table 1. As it can be noticed, resonant frequency is a direct function of the physical length of the letter which is highest for the alphabet letter "G". On the other hand, as shown Fig.3, the same letters also show higher resonant frequencies, which of course help in their specific identification.

B. *Letters showing peaks in 3-4 GHz*

This group comprises of the letters "J", "F", "L", "T" and "K". The shapes of letters in this group are pretty much similar to each other and are inter derivable. All the letters of this group have two resonance frequencies corresponding to two characteristic lengths (when considering vertical polarization).

Although letter "K" has a resonance larger than 4 GHz, but it has been included in this group because of the similarity with other letters of the group. As a result the resonance of letters "J", "L "and "T" are nearby, but J and L show higher resonant

TABLE II
RESONANT FREQUENCIES FOR F, J, K, L

Letters	F	J	K	L
Resonant	3.67	4	4.2	3.92
Frequency(GHz)	6	8.2	5.74	8

modes by which it is possible to differentiate them from "T".

Letters "F" and "K" show quite similar responses and both exhibit 2 resonant peaks. To understand the origin of these resonances, one can observe the current paths for each letter. Fig.4 shows the simulated currents for the two letters. We clearly distinguish two current paths for each letter. These peaks are due to 2 separate current paths as shown in the Fig. 4.

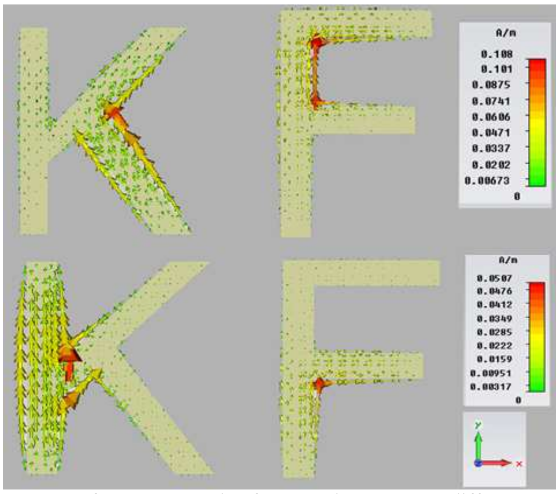

Fig. 4. Surface Current Plot for K and F, at two different resonant frequencies

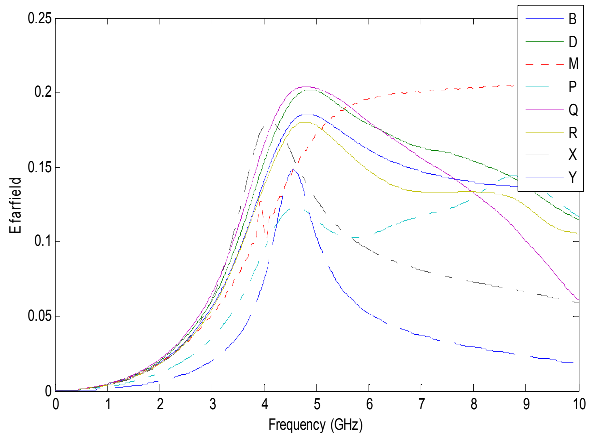

Fig. 5. Efarfield versus Frequency for letters B, D, M, P, Q, R, X and Y.

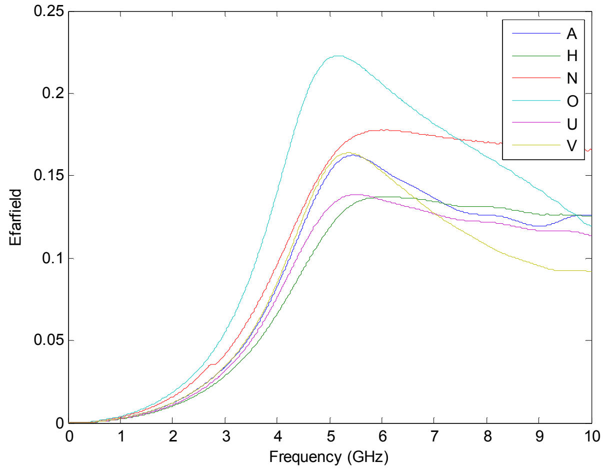

Fig. 6. Efarfield vs Frequency for Alphabets A, H, N, O, U and V

C. *Letters showing peaks in 4-6 GHz*

Letters "B", "D" , "K", "P", "Q", "R", "X", "Y" have peaks between 4 and 5 GHz. Most of the letters in this category show broadband peaks except "P", "X" and "Y". "P" exhibits a higher resonant frequency at 8.4 GHz because of current in the hook of "P" which is half the length of current path in vertical arm. The Efarfield versus frequency curves for some of the letters exhibiting broadband behavior is shown in Fig 5.

For letters "B", "D", "Q", "R" the current path is nearly similar in vertical direction, so their resonant peaks are nearby and are broadband. Similar situation exists for the letters showing peak in 5-6 GHz i.e. "U", "V", "A", "O", "N", "H". Only letter "O" can be recognized clearly in this group. Other letters are difficult to identify by looking at Efarfield response as seen in Fig 6. For this, we require an additional parameter that can help in the classification.

After analysis of letters with vertically polarized wave, it can be concluded that it is possible to uniquely identify the letters based on their resonant peaks. However, there are two set of alphabets which have similar response and it is difficult to clearly identify the correct letter. These 2 sets of letters comprise of :

- B, D, Q, R
- A, H, N, O, U, V

In order to uniquely identify these letters with high certainty, we require an additional parameter that can provide distinction between the responses. This could be achieved by analyzing the alphabets with horizontally polarized wave. Upon analyzing the letter placed in the same position with horizontally polarized wave, different surface current path is taken up by electrons because of the different shape along the incident wave's electric field. As a result we get different response. This is also analogous to rotating the alphabet by 90o in plane and keeping the wave polarization in the same direction. For the alphabets showing similar response with vertically polarized wave, we are able to get distinct separate response by rotating them by 90o. The first group of unresolved letters can be clearly resolved as seen in the Fig. 7.

If these letters are thought of in terms of rotation, it can be seen that on rotation by 90o letters "N" and "U" become similar to "Z" and "C". So, the current distribution is also

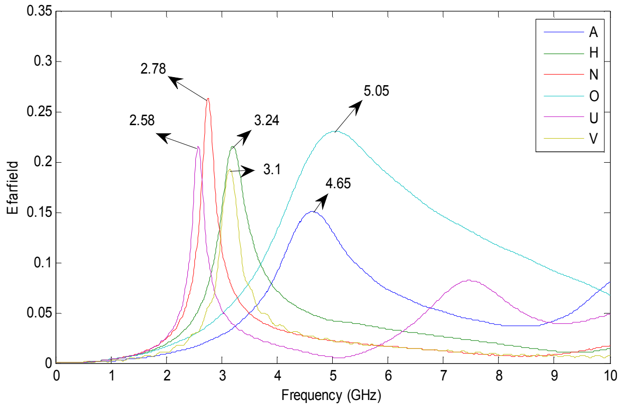

Fig. 7. Efarfield versus Frequency for letters A, H, N, O, U and V after rotation

similar and so are the resonant frequencies. For “U”, “V”, “N” now the surface currents flow through the whole length of the letter. Similarly the second group of letters can also be clearly resolved by this rotation.

So, as a conclusion, combining vertical and horizontal polarizations allow the identification of all the letters. This combining could be obtained either by circular polarization or more simply thanks to a slant polarization. On the other hand, simulations were also done for different font size of the alphabets and it was observed that by increasing/decreasing the size by a certain factor the resonant frequency decreases/increases by the same factor. So by keeping the results of font height 24 mm as a reference and using a proportionality constant it is possible to identify any alphabet of any size in Arial font. The same approach of identification can be developed for other fonts.

IV. Measurements

The results obtained in the simulation were verified with a monostatic measurement setup. The alphabet samples were realized using copper etching on a very thin kapton substrate of thickness 0.1mm and permittivity of 3.8. This leads to a very flexible mount. Fig.8 shows some of the realized samples corresponding to the Arial alphabet.

Each letter has a vertical size of 24mm (see Fig. 9 for letter “F”) chosen to generate an electromagnetic footprint presenting peaks and wells in the frequency range 1to 10 GHz. Moreover, the level of backscattered signals for such a size of letters remains significant and allows a reading range up to 50cm for the actual measurement set-up.

Measurements were done in an anechoic chamber setup using a VNA Agilent 8720D in monostatic radar setup as shown Fig. 10.

The chosen frequency span was 1 GHz to 10 GHz and the S11 parameter was measured. To calibrate the measurement system we eliminate the contribution due to horn antenna and the background thanks to a reference measurement that was taken and was subtracted from the subsequent measurements. In order to further enhance the signal, averaging was also used.

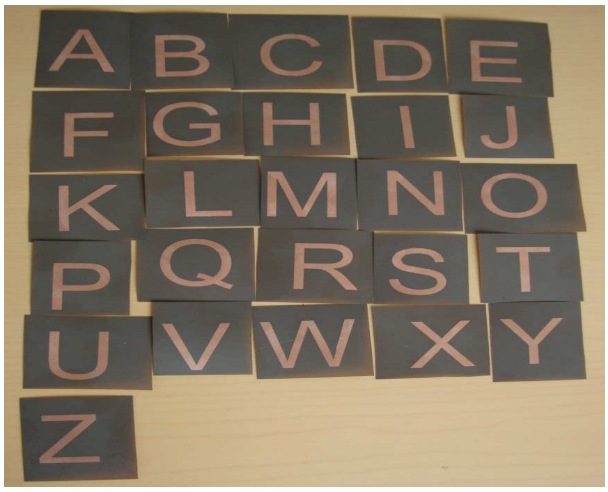

Fig. 8. Set of Letters Under Test

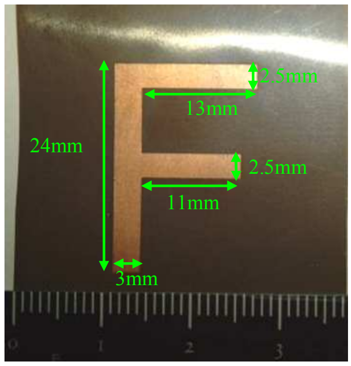

Fig. 9. View and dimensions for letter F.

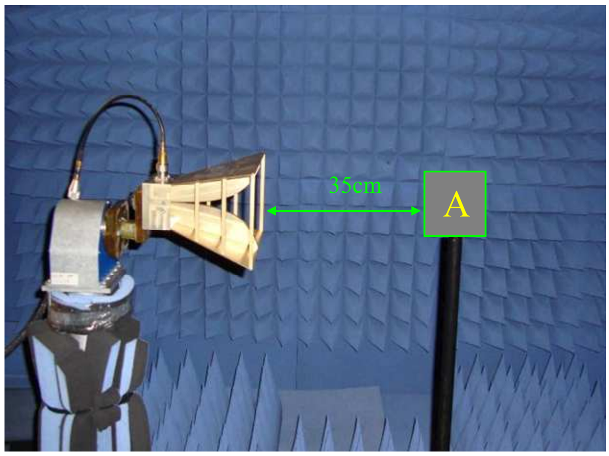

Fig. 10. Measurement Setup

A double-ridged horn antenna was used as shown in Fig. 10. The horn antenna has a gain close of 12dBi in the 0.7 to 18GHz range. Horn was fed with 2 meters of coaxial cables having an attenuation of 1dB/m. The Letter Under Test was at 36 cm from antennas. To get the magnitude found in the measurement, a calculation can be done using radar equation [7].

$$S_{11} = \frac{G^2 \cdot \lambda^2}{(4\pi)^3 R^4} \sigma \qquad (1)$$

In equation (1) R is the distance between the Letter Under Test and antennas, λ is the wavelength and G is the gain of horn antenna. The radar cross section "σ", as a function of frequency, is the result of this calculation.

Comparisons between simulations and measurement are given on Fig.11 and Fig.12. The simulated results are in very good agreement when compared to the measurements. Fig. 11 is for sharp resonances and concern letter "C", "Z", "E" and "G", while Fig.12 is for letters having broad resonance i.e. "O", "A", "X", "Y". In all cases experimental data confirm the simulation predictions.

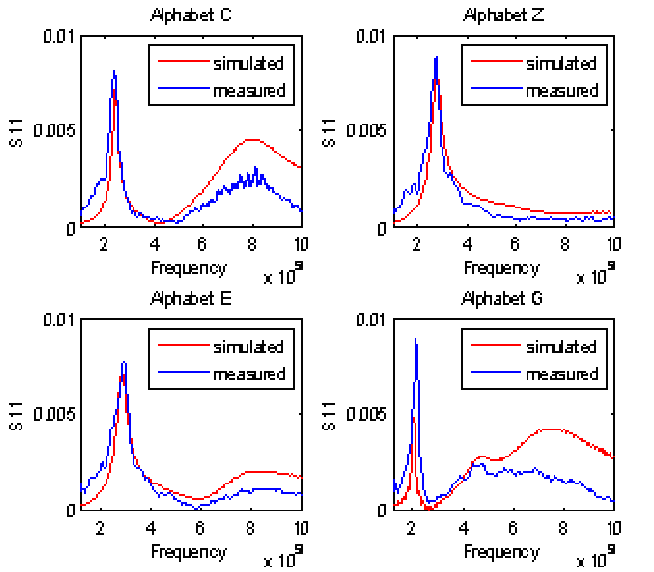

Fig. 11. Comparison between Simulated and Measured results for letters having sharp resonances.

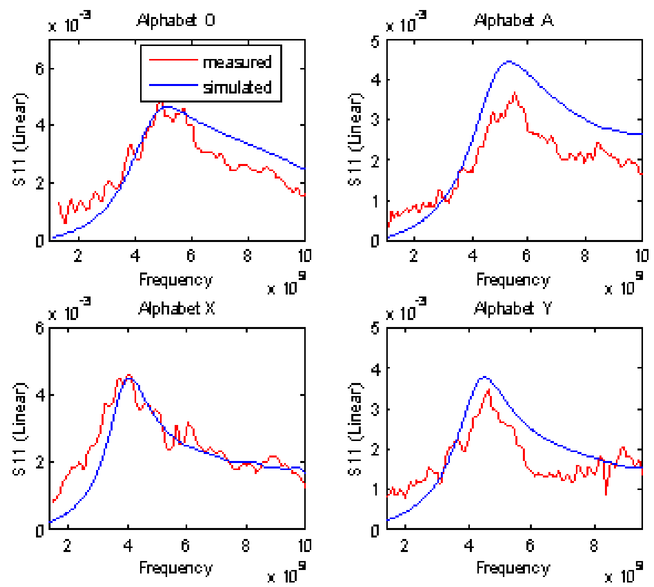

Fig. 12. Comparison between Simulated and Measured results for letters having broad resonances.

V. Conclusion

In this article we have presented a method for RF Identification of the alphabets. It was shown, by observing the resonant peaks, it is possible to uniquely identify the alphabet with high certainty. Simulations were confirmed by the measurements in the anechoic chamber.

For purposes of concept prove, we applied this approach to the Arial alphabet owing to its widespread use. The vertical letter size used was 24mm long in order to get resonances below 10GHz. For letters of different sizes resonances will be shifted. We checked this fact experimentally and only a scaling factor should be defined for identification purposes. The maximum factor for size reduction will be limit by measurement set-up and noise floor level of the environment. At present by this way we are able to identify only one letter at a time but this concept can be further expanded to consider letter association and words in future works.

Acknowledgment

The authors are grateful to the Centre Technique du Papier of Grenoble for supporting this project via the ACTRA program of the Région Rhône-Alpes.

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